The Intercomparison of Top-of-Atmosphere Reflectivity Measured by MERIS and SCIAMACHY in the Spectral Range of 443–865 nm

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***Abstract*—This letter is aimed at better understanding of Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY) reflectance radiometric calibration errors using the Medium Resolution Imaging Spectrometer (MERIS) onboard ENVISAT. Earlier investigations showed that the SCIAMACHY calibration error can reach 20% in the visible bands, which prevents aerosol retrievals using the SCIAMACHY data. Recent improvements of the SCIAMACHY calibration are discussed. It is found that the differences in reflectances for the wavelengths 443, 560, 665, 754, and 865 nm between MERIS and improved Processor 6 SCIAMACHY data are close to the MERIS radiometric calibration error, which is below 4%.**

***Index Terms*—Calibration, Medium Resolution Imaging Spectrometer (MERIS), Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY).**

I. Introduction

THE MEDIUM Resolution Imaging Spectrometer (MERIS) and the Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY) are instruments onboard the European Space Agency's ENVISAT satellite. The description of the instruments is given in [2] and [3]. SCIAMACHY is a hyperspectral spectrometer operating in the wavelength range of 240–2380 nm, with a variable resolution (0.2–0.5 nm for most of the measurements). MERIS provides the spectral top-of-atmosphere reflectance at 15 channels in the wavelength range of 412–900 nm, with widths depending on the channels but not larger than 10 nm for most of the channels. The spatial resolution of MERIS is 0.3×0.3 km^2 as compared to 30×60 km^2 (or even larger pixel sizes depending on spectral channels) for SCIAMACHY. It means that a single typical SCIAMACHY ground scene for the visible bands contains about 20 000 measurements of MERIS. This can be used, for example, for the improvement of a SCIAMACHY cloud screening algorithm because the measurements by both instruments are performed at the same time and area. For this and also for other applications, it is of importance to understand if MERIS and SCIAMACHY reflectances for the same area

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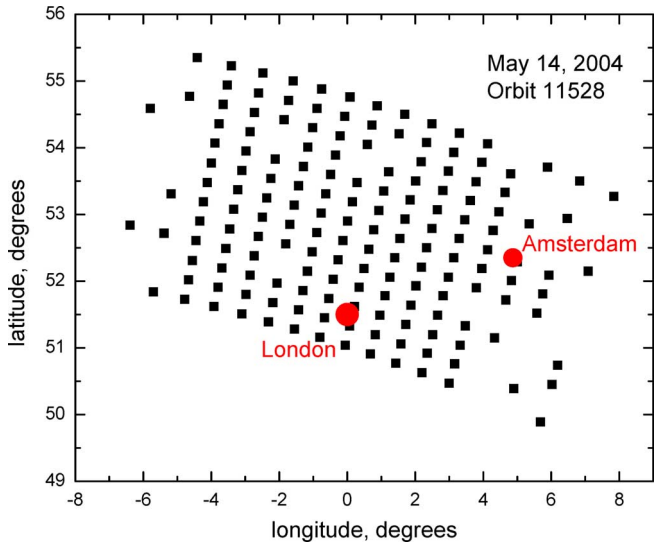

Fig. 1. Location of SCIAMACHY 30×60 km^2 pixels (black squares). One SCIAMACHY state for ENVISAT orbit 11528 (May 14, 2004) is shown.

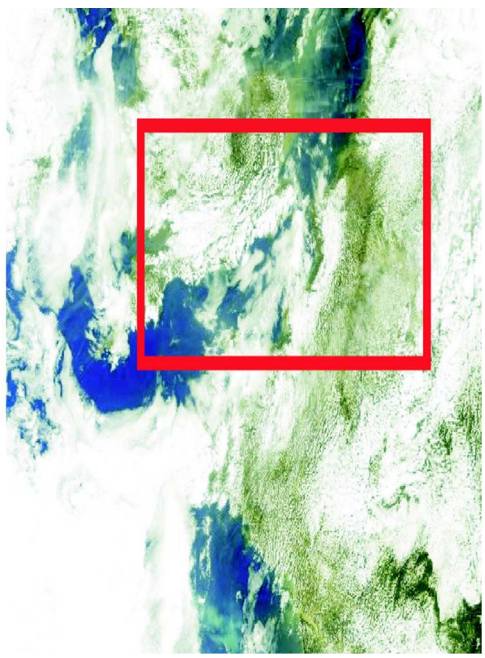

Fig. 2. Part of the MERIS browse image of orbit 11528 (May 14, 2004). The approximate location of the satellite measurements is shown by a box.

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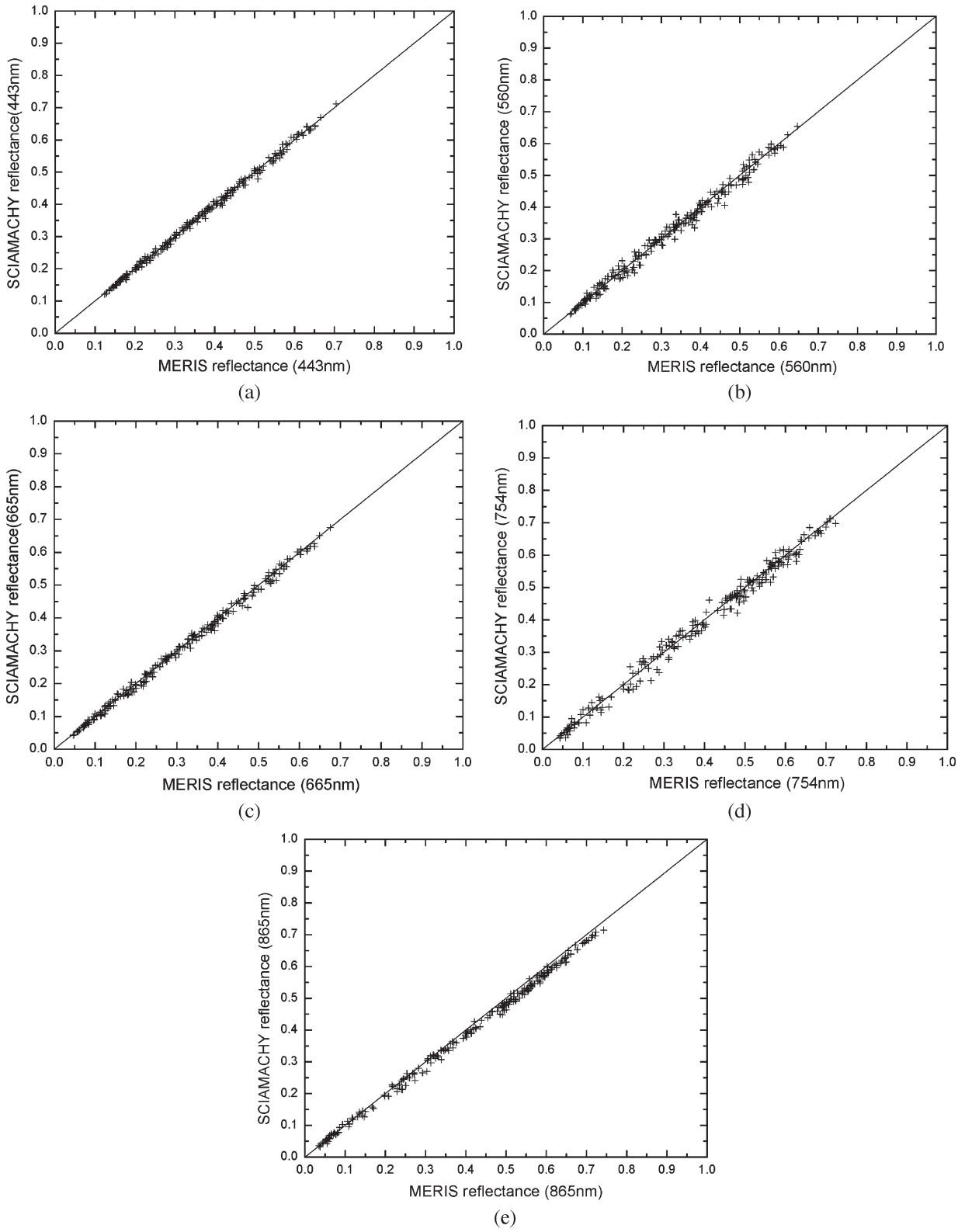

Fig. 3. Correlation between MERIS and SCIAMACHY reflectances for the wavelengths (a) 443, (b) 560, (c) 665, (d) 754, and (e) 865 nm.

coincide. This can be done by spatially averaging the MERIS reflectances to match larger SCIAMACHY ground scenes and by spectrally averaging the SCIAMACHY reflectances taking into account the MERIS spectral response functions for each channel. Such work has been performed in [1], [4], and [6]. It was demonstrated that the differences can reach 20% depending on the channels for the SCIAMACHY Processor 5 data. Recently, the ESA has released data from the improved SCIAMACHY Processor 6 data, where the radiometric calibration curve was considerably updated [5]. The task of

TABLE I
SPECTRAL DEPENDENCE OF THE CONSTANT A IN (2). ALSO, THE CORRELATION COEFFICIENT C AND THE STANDARD DEVIATION D ARE GIVEN. THE TOTAL NUMBER OF SCIAMACHY PIXELS STUDIED WAS EQUAL TO 208

λ,nm	A	C	D
443	0.9983	0.9975	0.0075
560	0.9867	0.9890	0.0156
665	0.9895	0.9966	0.0096
754	0.9902	0.9899	0.0191
865	0.9639	0.9978	0.0091

this letter is to compare the reflectances as measured by the ENVISAT MERIS and SCIAMACHY taking into account a new SCIAMACHY radiometric calibration curve.

II. MERIS AND SCIAMACHY REFLECTANCES: INTERCOMPARISON

MERIS and SCIAMACHY reflectances were intercompared for the SCIAMACHY state shown in Fig. 1. A part of a MERIS browse image containing this state is shown in Fig. 2. One can see that the broken cloud field existed over U.K. and parts of western Europe during measurements. Both clear and cloudy pixels over land and ocean were used in the intercomparison study. This enables to cover almost the entire range of the reflectance variability. The reflectance R is defined as

$$R = \frac{\pi I}{E_0 \cos \vartheta_0}. \tag{1}$$

Here, I is the top-of-atmosphere reflected light intensity, ϑ_0 is the solar zenith angle, and E_0 is the solar top-of-atmosphere irradiance on the area perpendicular to the solar beam. The value of R depends on the wavelength, and it is larger than approximately 0.2 in the visible region for cloudy ground scenes.

The results of the intercomparison study are reported in Fig. 3 and also in Table I, where the coefficients A of the statistical relationship

$$R_{\text{scia}} = AR_{\text{meris}} + B \tag{2}$$

are given. It was found that the offset B is smaller than 0.002 and can be neglected. The analysis of the data leads to the conclusion that current SCIAMACHY reflectance measurements are accurate (at least in the spectral range covered in this letter, 443–865 nm). The calibration of SCIAMACHY was improved considerably as compared to the SCIAMACHY Processor 5 version data [5].

The relative difference of MERIS and SCIAMACHY top-of-atmosphere reflectances $\delta = (R(\text{SCIAMACHY}) - R(\text{MERIS}))/R(\text{MERIS})$ is shown in Fig. 4. Also, the average value of δ and its standard deviation σ are given in Table II. It follows that the module of the average value of δ is smaller than

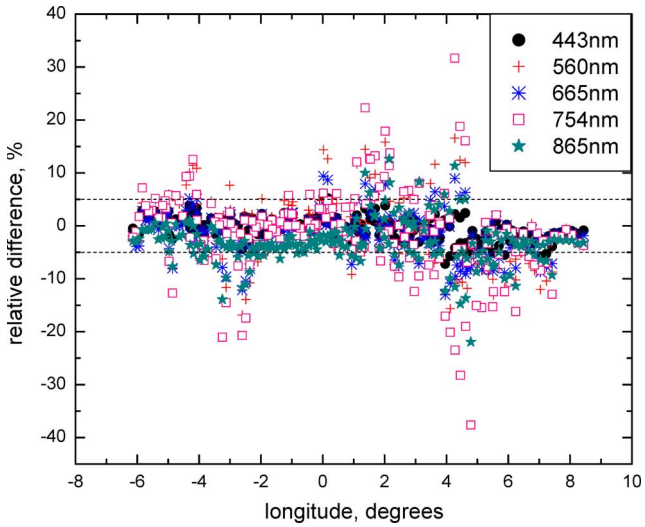

Fig. 4. Relative difference between SCIAMACHY and MERIS top-of-atmosphere reflectances as the function of the longitude for selected MERIS channels.

TABLE II
AVERAGE VALUE OF THE RELATIVE DIFFERENCE $\langle\delta\rangle$ AND ALSO ITS STANDARD DEVIATION σ (IN PERCENT) FOR THE CASE STUDIED AS THE FUNCTION OF THE WAVELENGTH. THE NUMBER OF POINTS IN THE STATISTICAL ENSEMBLE IS EQUAL TO 208

λ,nm	$\langle\delta\rangle$,%	σ,%
443	-0.5	2.2
560	-0.7	5.9
665	-1.5	3.9
754	-1.3	8.0
865	-3.1	4.2

4% for all the channels considered. This value does not differ significantly from the MERIS calibration error (±4% [3]).

This is an excellent result, which will enable accurate retrievals of atmospheric parameters like cloud and aerosol optical thicknesses as soon as all SCIAMACHY data are reprocessed using Processor 6.

III. CONCLUSION

SCIAMACHY has been almost five years in orbit. The instrument has produced a wealth of information on trace gases, aerosols, and clouds. Most of the atmospheric data were derived from relative spectral measurements using the differential optical absorption spectroscopy technique. Then, the calibration does not play a major role. However, for aerosol and cloud retrievals, the absolute value of the registered signal must be accurately known. In this letter, we demonstrate that the SCIAMACHY Processor 6 data agree well with the highly accurate (±4% calibration error) MERIS measurements in the visible and near infrared (up to 865 nm). In comparison, we have matched the SCIAMACHY and MERIS measurements both in spatial and spectral domains. The scan geometries

of SCIAMACHY and MERIS have been considered in the matching procedure. Also, MERIS spread point functions for each channel were taken into account.

Therefore, it is expected that SCIAMACHY aerosol, cloud, and, therefore, trace gas products will be improved after the planned reprocessing of measurements using SCIAMACHY Processor 6.

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